SNC1D/1P Sustainable Ecosystems/ Sustainable Ecosystems and Human Activity

Teacher Demo: Photosynthesis and Respiration: Complementary Processes

Topics	**Timing**
photosynthesis and respiration	preparation: 20 min
gas tests for oxygen and carbon dioxide	demonstration: 20 min

Introduction

The cells of green plants contain the pigment chlorophyll in organelles called chloroplasts. Chloroplasts capture the Sun's energy and store it—through photosynthesis—as chemical energy. The reactants for photosynthesis are water, $H_2O(l)$, and carbon dioxide, $CO_2(g)$. The products are carbohydrates, $C_6H_{12}O_6(aq)$, (compounds that store chemical energy) and oxygen, $O_2(g)$, which is released into the atmosphere. Photosynthesis can be summed up in the following equation:

$$\text{sunlight} + 6\ CO_2(g) + 6\ H_2O(l) \rightarrow 6\ O_2(g) + C_6H_{12}O_6(aq)$$

Cells of living organisms use the oxygen and carbohydrates thus produced to release energy in a process called cellular respiration, in which carbon dioxide is released. Cellular respiration can be summed up in the following equation:

$$6\ O_2(g) + C_6H_{12}O_6\ (aq) \rightarrow 6\ CO_2(g) + 6\ H_2O(l) + \text{energy}$$

Both animal and plant cells carry out cellular respiration to generate the energy needed for cellular processes.

Materials

- chemical safety goggles
- lab coat or apron
- protective gloves
- two 1000 mL beakers
- water at room temperature
- 8 small aquatic plants (e.g., *Elodea canadensis*)
- scissors
- 2 small, clear funnels to fit inside beakers
- 4 test tubes
- 2 laboratory stands and clamps
- grease pencil
- dropper bottle containing bromothymol blue indicator solution
- 4 stoppers to fit test tubes
- plastic wrap or aluminum foil
- plastic drinking straw
- test-tube rack
- barbecue lighter or match
- wood splint

Safety Considerations

- Provide MSDS sheets for all chemicals used.
- Remind students of emergency procedures related to fires (extinguisher use, fire exit, etc.).
- Ensure that the splints are completely extinguished before being throwing away.

Hazardous Materials Identification System Rating

(0-minimal 1-slight 2-moderate 3-serious 4-severe)

bromothymol blue
indicator solution

HMIS (0 to 4)

Health	**0**
Fire Hazard	**0**
Reactivity	**0**

Procedure

Wear appropriate PPE: chemical safety goggles, lab coat or apron, and protective gloves.
NOTE: Set up Demo 1 and Demo 2 on day 1 and make observations on day 2.

Demo 1 Set-up

1. Add approximately 700 mL of water to each of two 1000 mL beakers.
2. With scissors, cut the growing tip (about 3 cm long) off each of 6 elodea plants. Add 3 of the plant tips to each beaker with the cut ends pointing up.
3. Cover the elodea in beaker 1 with a funnel with the tip sticking up. The entire funnel should be below the water level.
4. Fill a test tube with water and invert it over the tip of the funnel (Fig.1). Clamp the test tube in place using a laboratory stand and clamp.

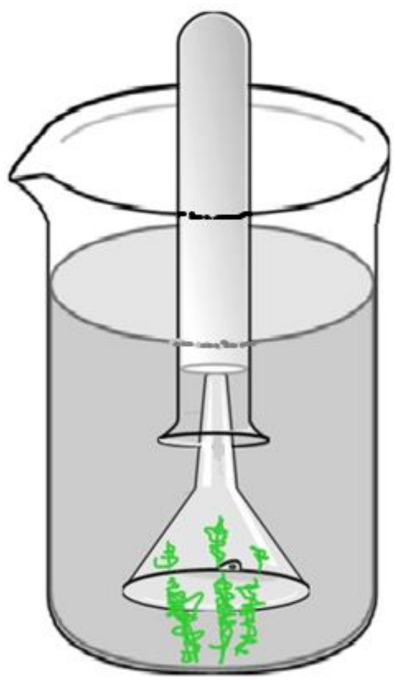

Fig.1 Set-up for Demo 1

5. Mark the water level in the test tube with a grease pencil.
6. Repeat Steps 3 to 5 for beaker 2.
7. **Predict/Explain**

Ask students, “What are the products of photosynthesis and respiration?” Ask students to clarify the connection between these two processes.

8. Ask students to *predict* what will happen in Demo 1, and to explain their predictions.
9. Allow the two beakers to sit overnight in a well-lit location.

Demo 2 Set-up

10. Label and half fill 2 test tubes with water.
11. Add 3 or 4 drops of bromothymol blue indicator to each test tube and allow students to observe the colour.
12. Cover test tube 1 with plastic wrap and then push the straw through and blow gently into the test tube for several minutes (until the solution turns yellow).
13. Allow students to compare the colours of the liquids in the two test tubes, and to provide an explanation for the colour change in test tube 1.
14. Add an elodea plant to each of test tubes 1 and 2 and place stoppers in the ends of the test tubes.
15. Place the test tubes in a test-tube rack and leave them in a well-lit location overnight.

Demo 1 Follow-up

16. **Observe**
    The next day allow students to observe the inverted test tubes in the beakers without touching them.
17. Lift one of the test tubes directly up out of the water, keeping it upside down. Place a stopper in the test tube then place it, right side up, in the test-tube holder.
18. **Explain**
    Ask students, “What evidence is there that something has happened in the test tube?” “How could we test for the gas produced?” Note: If students have already completed the chemistry unit, they will know the gas tests. If not, then discuss with students what a fire needs to keep burning. Explain that a glowing splint when placed in oxygen gas will reignite.

Discuss emergency fire safety procedures with the students (including fire extinguisher use, fire exit, etc.).

19. Light a wooden splint with the barbecue lighter. Blow out the splint’s flame but allow some embers to remain glowing. Remove the stopper from the test tube and place the glowing splint into the test tube.
20. When the splint relights, remove it and blow it out. Make sure that the splint is fully extinguished (place it in water) before disposal.
21. To illustrate this again repeat Steps 16 to 19 with the test tube from second beaker.

Demo 2 Follow-up

22. **Observe**
    Allow students to observe the two test tubes containing bromothymol blue indicator and elodea plants. Encourage them to recall what they observed and inferred the previous day about any gases dissolved in the water. What has changed?
23. **Explain**
    Encourage students to suggest what gas was produced by photosynthesis and what gas was used by the plant in photosynthesis.

Disposal

Dispose of the bromothymol blue solution in the chemical waste container. Elodea plants could be given to the Biology classes for further investigations. Alternatively they should be placed in the municipal organics collection container, or in the regular garbage. The rest of the equipment should be cleaned thoroughly and stored for later use. Follow disposal procedures that are consistent with school board protocol and appropriate for your municipality.

What happens?

- Day 1, Demo 2: When you blow into the bromothymol blue solution, the liquid turns yellow.
- Day 2, Demo 1: The top of the inverted test tubes are filled with oxygen-rich air, as shown by the test for oxygen.
- Day 2, Demo 2: the yellow solution with the elodea plant in test tube 1 turns back to blue. The blue solution with the elodea plant in test tube 2 will not change colour.

How does it work?

In Demo 1, oxygen gas is produced as the elodea undergoes photosynthesis. The oxygen rises through the funnel and into the test tube, displacing some of the water. Since oxygen supports combustion, the glowing splint relights when it is inserted into the test tube.

The bromothymol blue solution used in Demo 2 is an acid–base indicator. Bromothymol blue is blue above a pH of 7.6 (in neutral and basic solutions) and yellow in acidic solutions where the pH is below 6.0. When exhaled air (containing carbon dioxide, $CO_2(g)$) is blown into the water in test tube 1, the carbon dioxide reacts with water to produce a solution of carbonic acid, $H_2CO_3(aq)$.

$$CO_2\,(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$

The increased acidity of the solution changes the indicator colour from blue to yellow. Overnight, the elodea plant photosynthesizes, consuming carbon dioxide and releasing oxygen. As a result, the solution becomes less acidic and the colour reverts to blue. The solution in test tube 2 does not change colour, implying no significant change in pH, because there was no additional carbon dioxide added on day 1for the plant to consume.

Teaching Suggestions/Hints

1. Leave Demos 1 and 2 overnight under a bright light for best results.
2. When performing the oxygen test in Demo 1, do not remove the stopper until you have the glowing splint ready. Remove the stopper and quickly insert the glowing splint.
3. Demo 1 is set up twice so that there is a backup in case the oxygen test fails to work for one of the test tubes.

Next Steps

Discuss the importance of the energy conversion when sunlight is used to produce carbohydrates. This is the beginning of all energy pathways in ecosystems that depend on photosynthesis.

Additional Resources

1. Video showing photosynthesis with phenol red indicator - http://www.youtube.com/watch?v=QCDRq6u8tCg
2. Video showing the effect of carbon dioxide on bromothymol blue indicator - http://www.youtube.com/watch?v=fuOMKWBDAT0

Specific Expectations

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A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions

B3.2 describe the complementary processes of cellular respiration and photosynthesis with respect to the flow of energy and the cycling of matter within ecosystems (i.e., carbon dioxide is a by-product of cellular respiration and is used for photosynthesis, which produces oxygen needed for cellular respiration), and explain how human activities can disrupt the balance achieved by these processes (e.g., automobile use increases the amount of carbon dioxide in the atmosphere; planting more trees decreases the amount of carbon dioxide in the atmosphere)

C2.4 conduct appropriate chemical tests to identify some common gases (e.g., oxygen, hydrogen, carbon dioxide) on the basis of their chemical properties, and record their observations [PR, C]

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C2.7 conduct chemical tests to identify common gases (e.g., oxygen, hydrogen, carbon dioxide) on the basis of their chemical properties, and record their observations [PR, AI, C]